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WEEDS IN ORGANIC BEAN CROPS (*PHASEOLUS VULGARIS* L.) (FABACEAE LINDL., FABALES)

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SUMMARY

In the organic bean crops (*Phaseolus vulgaris*) grown in open cultivation during the vegetation period of 2012, 14 weed species were found in the villages Ljutovo and Orom. The percentage of invasive species was 28.57%. *Ambrosia artemisiifolia* was characterized as highly invasive, *Sorghum halepense* as sporadically invasive, and *Amaranthus retroflexus* and *Datura stramonium* as potentially invasive species. Low diversity and low density of weed flora in organic bean crops are the factors causing a high percentage of invasive species in the floristic composition, so monitoring of these species is necessary. The weed flora dominated by therophytes (71.43%), the dominance of weed-ruderal plants (64.29%), and the presence of widespread taxa in the bean crops indicate strong anthropogenic influence and instability of the weed flora. The largest number of the weed species bloom from June to August (71.43%). According to the ecological analysis of the weed flora, the studied agroecosystems were characterized as moderately arid (F-2.36), neutral to weakly alkaline (R-3.07), eutrophic-mesotrophic (N-3.71), well-aerated (D-3.64), non-saline (S-, 78.57%) with medium humus content (H-2.86), favorable light (L-3.86) and temperature (T-4.14) regime, and with temperate continental climatic conditions (K-2.93). Correlation analysis showed that invasive weed species began to bloom later and favored well-aerated and warmer habitats compared to other weeds. PCA analysis singled out habitat aeration and salinity as the main factors separating weeds in organic bean crops.

Key words: *Phaseolus vulgaris*, organic farming, weeds

INTRODUCTION

Phaseolus vulgaris L. (bean) is an annual plant of the Fabaceae family. The main root is poorly developed, and the lateral roots are numerous and long. The stem is erect, 0.5-1 m high, branched, furrowed, and covered with protruding and short hairs. It has a trifoliate leaf on long petiolate, with small lanceolate stipules. The leaflets are ovate, with pointed apex, and rounded or wedge-shaped at the base, 5-20 cm long, light to dark green. The flowers are 1-1.5 cm long, with yellowish to greenish-white or pink petals. There are 2-6 (rarely 19) flowers arranged in opposite pairs, forming an upright inflorescence. The legume is 10-20 (30) cm long, 1-2 (3) cm wide, flattened, monochromatic, green to yellowish-white, or purple-violet, with 2-8 (rarely 9) seeds. Bean blooms from June to September (Josifović, 1970-1977).

As an economically viable plant species and a good pre-crop, bean is very common in vegetable production in Serbia. It can fix more than 160 kg of atmospheric nitrogen per ha of soil by interacting with *Rhizobium* bacteria. Bean occupies an important place in human diet because of its high nutritional value and high content of proteins, minerals, and fibers. It also contains water-soluble vitamins such as B1, B2, B3, B6, and folic acid, as well as the minerals potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), and iron. (Fe) (Celmeli et al., 2018). It is also used in livestock production, in the citric acid industry, for obtaining flour that is added to pasta to improve its quality.

Soil suitable for bean production is fertile, loose, well-aerated and moderately moist soil of neutral reaction (pH 6.5-7.5) (Todorović et al., 2008). In organic bean farming, special attention must be paid to weeds. While in conventional farming weeds are eliminated for the harm they cause to the cultivated plant, in organic farming weeds are also viewed from a positive aspect, and the goal is not to destroy weeds but to bring them into balance with the cultivated plant. Weed development in organic farming is controlled by: proper selection of plant sorts, time and method of planting, crop rotation, consociation, tillage that creates favorable conditions for development of natural pests, physical and mechanical weed control, etc. (Sekulić et al., 2008). Weed control in organic farming is based on efficiency of the entire production system and a combination of permitted methods without environmental consequences (Šeremešić & Milošev, 2008). Therefore, the aim of this paper was to study weed flora in organic bean crops, including ecological and plant-geographic analysis, analysis of flowering time, categorization of weeds according to habitat, presence of invasive species, as a necessary precondition in selecting measures of weed control in organic farming.

MATERIAL AND METHODS

Floristic and ecological studies of weed flora in organic bean production (*Phaseolus vulgaris*) in open cultivation were performed during the vegetation period of 2012 in the area of the villages Ljutovo (Biofarm “Mamudžić”) and Orom (“Biosalaš Farago”). The following white bean sorts were used: Belko, Maksa, Balkan, and Dvadesetica (sorts of the Institute of Field and Vegetable Crops, Novi Sad) and Galeb (sort of the Institute of Vegetable Crops in Smederevska Palanka). Weed determination was performed according to Josifović (1970-1977). The analyzed characteristics of the identified weed taxa included: life form (Ujvárosi, 1973), flowering month and categorization according to habitat (Čanak et al., 1978), floral elements (Gajić, 1980) and ecological indices (Landolt, 1977). The status of invasiveness in Serbia for invasive species is given according to Lazarević et al. (2012). Correlation analysis and PCA analysis were performed to determine the relationships between the eco-biological characteristics of the weeds. The analyzed variables were transformed as shown in Table 1. All statistical analyses were performed using STATISTICA 13.2 software (Dell™ Statistica™ 13.2 University License).

Table 1. Transformation of the analyzed characteristics of weed species

Characteristics	Transformations and meanings	
life forms	1	T ₄ therophytes
	2	G ₃ geophytes
	3	G ₁ geophytes
flowering beginning	5	May
	6	Jun
	8	August
flowering ending	6	Jun
	7	July
	8	August
	9	September
flowering length	10	October
	1	1 month
	2	2 months
	3	3 months
	4	4 months
weed category	5	5 months
	1	segetal weeds
	2	weed-ruderal plants
	3	ruderal plants
floral element	4	meadow weeds
	1	Adventive
	2	Subeurasian
	3	Eurasian
	4	Cirkumpolare
invasiveness	5	Cosmopolitan
	0	no invasive species
	1	potentially invasive species
	2	sporadically invasive species
	3	highly invasive species

moisture - F	1	xerophytes
	2	subxerophytes
	3	mesophytes
	4	hygrophytes
chemical reaction - R	2	acid habitat
	3	neutrophilic plants
	4	neutral to alkaline habitat
nutrients content - N	3	mesotrophic habitat
	4	eutrophic habitat
	5	extremely eutrophic habitat
humus content - H	2	habitat with low humus content
	3	habitat with medium humus content
	4	habitat rich in humus content
aeration - D	2	good aerated habitat
	3	moderately aerated habitat
	4	poorly aerated habitat
	5	badly aerated habitat
salinity - S	0	non-saline habitat
	1	saline habitat
light - L	3	semi-shade habitat
	4	well lit habitat
temperature - T	3	mesothermic plants
	4	thermofilic plants
	5	extremely thermofilic plants
continentality - K	2	suboceanic climate conditions
	3	out-of-continental climate conditions

RESULTS AND DISCUSSION

A total of 14 plant species were found in the organic bean crops: 12 species in Ljutovo and 7 species in Orom (Table 2). Plant species found in both localities included: *Ambrosia artemisiifolia*, *Convolvulus arvensis*, *Datura stramonium*, *Solanum nigrum* and *Sorghum halepense*. In addition, *Alopecurus pratensis*, *Amaranthus retroflexus*, *Cirsium arvense*, *Chenopodium album*, *Eragrostis minor*, *Panicum crus-galli* and *Setaria glauca* were identified only in Ljutovo, while *Bilderdykia convolvulus* and *Portulaca oleracea* were found only in Orom.

Table 2. Weeds in organic bean crops with invasive status

Plant species	Family	Abbreviation	Ljutovo	Orom	Invasiveness in Serbia
<i>Alopecurus pratensis</i> L.	Poaceae	ALOPR	+1	-	
<i>Amaranthus retroflexus</i> L.	Amarantaceae	AMARE	1.1	-	PI
<i>Ambrosia artemisiifolia</i> L.	Asteraceae	AMBAR	+1	+1	HI
<i>Bilderdykia convolvulus</i> (L.) Dum.	Polygonaceae	BILCO	-	+1	
<i>Cirsium arvense</i> (L.) Scop.	Asteraceae	CIRAR	+1	-	
<i>Chenopodium album</i> L.	Chenopodiaceae	CHEAL	+1	-	
<i>Convolvulus arvensis</i> L.	Convolvulaceae	CONAR	+1	+1	
<i>Datura stramonium</i> L.	Solanaceae	DATSR	+1	+1	PI
<i>Eragrostis minor</i> Host.	Poaceae	ERAMI	+1	-	
<i>Panicum crus-galli</i> L.	Poaceae	PANCG	+1	-	
<i>Portulaca oleracea</i> L.	Portulacaceae	POROL	-	+1	
<i>Setaria glauca</i> (L.) P.B.	Poaceae	SETGL	+1	-	
<i>Sorghum halepense</i> (L.) Pers.	Poaceae	SORHA	+1	+1	SI
<i>Solanum nigrum</i> L.	Solanaceae	SOLNI	+1	+1	

Legend: HI – highly invasive in Serbia; PI – potentially invasive in Serbia; SI – sporadically invasive in Serbia

Taxonomic analysis of the studied flora shows that all identified plant species are classified in the division Magnoliophyta (Tab. 2). Nine plant species (64.28%) from seven families belong to the class Magnoliopsida (dicotyledons), while five plant species (35.71%) from the family Poaceae belong to the class Liliopsida (monocotyledons). Poaceae family was the richest in plant species (5 taxa, 35.71%). It was followed by the families Solanaceae (2 taxa, 14.28%), Asteraceae (2 taxa, 14.28%) and Amaranthaceae, Polygonaceae, Chenopodiaceae,

Convolvulaceae and Portulacaceae, which were present with only one species (7.14%). The presence of invasive species in the studied weed flora of bean was 28.57%, 4 plant species (4 taxa, 33.33% in Ljutovo and 3 taxa, 42.86% in Orom). According to Lazarević et al. (2012), *Ambrosia artemisiifolia* is characterized as highly invasive, *Sorghum halepense* as sporadically invasive, and *Amaranthus retroflexus* and *Datura stramonium* as potentially invasive species. Our results are consistent with the studies which indicate a negative correlation between the richness of native species and occurrence of invasive species, and which report that floristically poor communities are “vulnerable” to invasion (Kennedy et al., 2002; Chytrý et al., 2005; Gilbert & Lechowicz, 2005). Thus, the floristically poor weed flora of bean failed to resist the occurrence of invasive species, which refers primarily to the locality of Orom. Hussner & Lösch (2005) state that the presence of alien species is enabled by availability of free heterogeneous niches in the phytocenosis.

Table 3. Biological and ecological weed characteristics in organic bean crops

Plant species	Life form	Category according to the site	Floral element	Ecological indices									
				F	R	N	H	D	S	L	T	K	
<i>Alopecurus pratensis</i> L.	G ₁	LK,KR	Evr.	4	3	4	3	5	-	4	3	3	
<i>Amaranthus retroflexus</i> L.	T ₄	KR	Adv.	2	3	4	3	3	-	4	4	3	
<i>Ambrosia artemisiifolia</i> L.	T ₄	R	Adv.	2	3	4	2	2	+	4	5	3	
<i>Bilderdykia convolvulus</i> (L.) Dum.	T ₄	S	Subevr.	2	3	3	3	4	-	4	4	3	
<i>Cirsium arvense</i> (L.) Scop.	G ₃	KR	Subevr.	3	3	4	3	4	+	3	4	3	
<i>Chenopodium album</i> L.	T ₄	KR	Kosm.	2	3	4	3	4	-	4	3	3	
<i>Convolvulus arvensis</i> L.	G ₃	KR	Kosm.	2	4	3	3	4	-	4	4	3	
<i>Datura stramonium</i> L.	T ₄	R	Kosm.	3	3	4	4	4	+	4	5	2	
<i>Eragrostis minor</i> Host.	T ₄	KR	Cirk.	1	3	2	2	3	-	4	5	3	
<i>Panicum crus-galli</i> L.	T ₄	S	Kosm.	3	3	5	3	4	-	3	4	3	
<i>Portulaca oleracea</i> L.	T ₄	KR	Kosm.	3	3	4	3	4	-	4	4	3	
<i>Setaria glauca</i> (L.) P.B.	T ₄	KR	Kosm.	2	3	4	2	3	-	4	4	3	
<i>Sorghum halepense</i> (L.) Pers.	G ₁	KR	Kosm.	1	2	3	3	3	-	4	5	3	
<i>Solanum nigrum</i> L.	T ₄	KR	Kosm.	3	4	4	3	4	-	4	4	3	

Legend: T- therophyte; G – geophyte; KR weed - ruderal; R – ruderal; S – segetal weed; LK – meadow weed; Adv. – Adventive; Evr.- Eurasian; Kosm. – Cosmopolitan; Cirk.- Cirkumpolare; Subevr. – Subeurasian

Out of the total number of the identified species, nine species were weed-ruderal plants (64.29%), two were ruderal (14.28%) and two were segetal weeds (14.28%). *Alopecurus pratensis* belongs to the category of meadow weeds, but it is also characterized as a weed-ruderal plant.

The analyzed weed species bloom from May to October (Fig. 1). The largest number of weed species (10 species) bloom from June to August. *Alopecurus pratensis* and *Eragrostis minor* bloom in May. Six taxa bloom in September (*Datura stramonium*, *Convolvulus arvensis*, *Chenopodium album*, *Bilderdykia convolvulus*, *Ambrosia artemisiifolia* and *Amaranthus retroflexus*) and *Solanum nigrum* in October and it has the longest flowering period, from June to October.

Analysis of life forms showed that the studied flora was dominated by therophytes, and all present therophytes were from T₄ category (10 taxa, 71.43%) i.e. they germinate in spring, and their seeds mature in late summer. Geophytes accounted for 28.57% of the studied flora (4 taxa; G₃ – 2 taxa, 14.28% and G₁ – 2 taxa, 14.28%). These results are a consequence of mechanical weed control (hilling), which is favorable for survival of therophytes. Such biological spectrum is characteristic of ecosystems under strong anthropogenic influence and it indicates instability of weed flora (Nikolić et al., 2011; Džigurski et al., 2012).

Figure 1. Flowering time of weeds in organic bean crops

Analysis of the ecological index for moisture indicates the dominance of subxerophytes (F_2), adapted to relatively dry habitats (6 taxa, 42.86%) and mesophytes (F_3), adapted to moderately moist habitats (5 taxa, 35.71%). Only *Eragrostis minor* and *Sorghum halepense* were adapted to dry habitats (F_1 : 2 taxa, 14.29%). Hygrophyte *Alopecurus pratensis* is an indicator of wet habitats (F_4 : 1 taxon, 7.14%) and it was present only in the location of Ljutovo. The dominance of subxerophytes and the mean value of the ecological index for moisture (F-2.36) indicate moderately dry conditions of the investigated agroecosystems (Fig. 2).

Analysis of the ecological index for chemical reaction of the substrate reveals a significant presence of neutrophilic plants – R_3 (11 taxa, 78.57%), Fig. 2. They were followed by indicators of neutral to a slightly alkaline habitat – R_4 (2 taxa, 14.29%) and an indicator of acid habitat – R_2 (1 taxon, 7.14%). According to the mean value of the ecological index for chemical reaction of the soil (R-3.07), it is a neutral to slightly alkaline substrate, which is expected given that bean does not tolerate acid reaction of the soil, and its cultivation on such substrates is avoided.

Regarding the content of nitrogen and nitrogenous substances, indicators of eutrophic ecosystem – N_4 (9 taxa, 64.29%) and extremely eutrophic ecosystem – N_5 (1 taxon, 7.14%) were dominant. The presence of indicators of mesotrophic ecosystems – N_3 (3 taxa, 21.43%) and indicators of relatively low content of nitrogenous substances – N_2 (1 taxon, 7.14%) was significantly lower. The mean value of N-3.71 also indicates eutrophic-mesotrophic conditions of the studied agroecosystem (Fig. 2).

Analysis of the ecological index for humus content was dominated by plants with medium requirements for humus content – H_3 (10 taxa, 71.43%). The presence of indicators of the substrate with low humus content – H_2 (3 taxa, 21.43%) and indicators of the substrate relatively rich in humus – H_4 (1 taxon, 7.14%) was significantly lower. The medium humus content was confirmed also by the mean value (H-2.86) for the analyzed agroecosystems (Fig. 2).

Analysis of the ecological index for substrate aeration revealed a significant presence of indicators of well-aerated substrate – D_4 (8 taxa, 57.14%). They were followed by indicators of very well-aerated substrate – D_3 (4 taxa, 28.57%), extremely well-aerated substrate – D_2 (1 taxon, 7.14%) and unfavorable aerated substrate – D_5 (1 taxon, 7.14%). The mean value of the ecological index for aeration (D-3.64) showed that the weed flora of bean was adapted to a well-aerated substrate (Fig. 2).

Analysis of the ecological index for salinity shows the dominance of indicators of non-saline habitats – S_1 (11 taxa, 78.57%). Taxa that tolerate higher Na^+ ion content – S_+ (3 taxa, 21.43%) in Ljutovo (*Ambrosia artemisiifolia*, *Datura stramonium* and *Cirsium arvense*) and Orom (*Ambrosia artemisiifolia* and *Datura stramonium*) indicate the presence of some saline places of these habitats (Fig. 2, Tab. 3).

The dominance of indicators of well-lit habitats – L_4 (12 taxa, 85.71%) and the average value of the ecological index for light (L-3.86) indicate a favorable light regime of this agroecosystem (Fig. 2). Semisciophytes (L_3) *Panicum crus-galli* and *Cirsium arvense* are indicators of semi-shade habitat (2 taxa, 14.29%).

Analysis of the ecological index for temperature reveals predominance of indicators of warm habitats – T_4 (8 taxa, 57.14%) and extremely warm habitats – T_5 (4 taxa, 28.57%). They were followed by indicators of moderately warm habitats – T_3 (2 taxa, 14.29%). The communion of indicators of warm (T_4) and extremely warm habitats (T_5) of 85.71% and the mean value of the ecological index (T-4.14) indicate a favorable temperature regime (Fig. 2). It is

necessary to point out that thermophilic invasive species *Ambrosia artemisiifolia*, *Datura stramonium* and *Sorghum halepense*, which are present in both localities, favor warm habitat conditions (Tab. 3).

Figure 2. Percentage presence of weed species characterized by ecological indices in organic bean crops

According to analysis of the ecological index for continentality, indicators of moderate continental habitat conditions – K₃ (13 taxa, 92.86%) are dominant. Indicators of suboceanic climate are present with one taxon – K₂ (7.14%). Moderate continental climatic conditions are also confirmed by the average value for continentality (K-2.93), Fig. 2. The weed flora of organic bean crops was absolutely dominated by widespread plants, which is typical for weed vegetation, and it stems from their wide ecological valence and highly manifested properties of plasticity and adaptability. The floral elements included: Cosmopolitan (8 taxa, 57.14%), Adventive (2 taxa, 14.28%), Subeurasian (2 taxa, 14.28%), Eurasian (1 taxon, 7.14%) and Circumpolar (1 taxon, 7.14%).

Correlation analysis showed significant correlations among the studied eco-biological characteristics of weeds (Tab. 4), which is in accordance with our previous results (Ljevnaić-Mašić et al., 2019; Ljevnaić-Mašić et al., 2020). Weed species that had a longer flowering period ended flowering later ($r = 0.86^*$). Invasive weed species began to bloom later ($r = 0.72^*$) and favored well-aerated ($r = -0.71^*$) and warmer habitats ($r = 0.62^*$) compared to non-invasive weeds. The beginning of flowering depended on the habitat aeration ($r = -0.61^*$). Namely, the species that started flowering earlier favored less aerated habitats compared to the species that bloomed later in better-aerated habitats. Habitat aeration was correlated with temperature ($r = -0.67^*$) and habitat humidity ($r = 0.71^*$), as well as with humus content in the soil ($r = 0.63^*$). Namely, colder and wetter habitats, as well as habitats with higher humus content, had unfavorable habitat aeration. Furthermore, humus content was negatively correlated with climatic conditions ($r = -0.62^*$). Species adapted to non-continental climatic conditions favored habitats with higher humus content. Increased habitat humidity also caused increased nutrient content in the soil ($r = 0.68^*$).

PCA analysis explained 41.08% of the variability and singled out habitat aeration (PC1: 0.94) and salinity (PC2: -0.75) as the main components separating the weeds in organic bean crops (Fig. 3). PC1 separated weed species that favored better-aerated habitats from the species adapted to unfavorable habitat aeration. PC2 separated weed species less adapted to saline habitats from species adapted to higher salt concentrations in the soil.

Figure 3. Relationship among weed species and their eco-biological characteristics in organic bean crops (PCA analysis)

Table 4. Correlations among eco-biological characteristics of weed species in organic bean crops

Variable	plant species	life form	flowering beginning	flowering ending	flowering length	weed category	floral element	invasiveness	F	R	N	H	D	S	L	T	K
plant species	1.00	-0.12	-0.11	-0.12	-0.07	-0.38	0.79*	-0.15	-0.21	0.02	-0.05	-0.03	-0.09	-0.28	0.00	0.31	-0.03
life form		1.00	-0.30	-0.42	-0.27	0.42	0.02	0.11	0.10	-0.31	-0.18	0.16	0.29	-0.07	-0.04	-0.13	0.16
flowering beginning			1.00	0.34	-0.18	-0.00	-0.35	0.72*	-0.13	0.00	0.31	-0.21	-0.61*	0.53	0.00	0.34	0.00
flowering ending				1.00	0.86*	-0.09	-0.21	0.15	-0.16	0.48	-0.22	0.23	-0.13	0.24	0.34	0.16	-0.20
flowering length					1.00	-0.09	-0.03	-0.23	-0.10	0.50	-0.39	0.36	0.19	-0.03	0.36	-0.01	-0.21
weed category						1.00	-0.16	0.32	0.39	-0.03	0.08	0.05	0.10	0.37	0.35	-0.04	-0.32
floral element							1.00	-0.38	0.00	0.12	0.01	0.23	0.31	-0.37	0.07	-0.04	-0.21
invasiveness								1.00	-0.34	-0.43	-0.00	-0.15	-0.71*	0.48	0.23	0.62*	-0.15
F									1.00	0.32	0.68*	0.46	0.71*	0.20	-0.32	-0.51	-0.22
R										1.00	0.06	0.04	0.30	-0.08	0.06	-0.28	0.04
N											1.00	0.28	0.22	0.21	-0.46	-0.39	-0.11
H												1.00	0.63*	0.14	-0.11	-0.16	-0.62*
D													1.00	-0.23	-0.20	-0.67*	-0.14
S														1.00	-0.28	0.43	-0.53
L															1.00	0.09	-0.11
T																	
K																	

Legend: * - significant correlations $p < 0.05$; F – moisture; R – chemical reaction; N – nutrients content; H – humus; D – aeration; S – salinity; L – light; T – temperature; K – continentality
negative correlations (r ranged from -1.0 to 0.00)
positive correlations (r ranged from 0.00 to 1.0)

CONCLUSION

The weed flora in the organic bean farming in open cultivation found in the villages Ljutovo and Orom consists of 14 taxa. All identified plant species belonged to the division Magnoliophyta, while the family Poaceae was the richest in plant species. The invasive species accounted for 28.57% of the studied weed flora. *Ambrosia artemisiifolia* is characterized as highly invasive, *Sorghum halepense* as sporadically invasive, and *Amaranthus retroflexus* and *Datura stramonium* as potentially invasive species. Low diversity and low density of the weed flora are some of the factors causing high occurrence of invasive species in the floristic composition, and it is necessary to monitor these species and prevent potential occurrence of new invasive species. The largest number of weed species blooms from June to August (71.43%), while *Solanum nigrum* has the longest flowering period. The studied weed flora was dominated by therophytes (71.43%), and weed-ruderal plants (64.29%), indicating strong anthropogenic influence and instability of the weed flora. The studied agroecosystems were characterized as moderately arid (F-2.36), neutral to weakly alkaline (R-3.07), eutrophic-mesotrophic (N-3.71), with medium humus content (H-2.86), good aeration (D-3.64), nonsaline (S-78.57%), with favorable light (L-3.86) and temperature (T-4.14) regime and with temperate continental climatic conditions (K-2.93). Plant-geographical analysis of the weed flora indicated the absolute dominance of widespread taxa. Correlation analysis showed that invasive weed species bloom later and favor well-aerated and warmer habitats compared to other weeds. PCA analysis singled out habitat aeration and salinity as the main factors separating weeds in organic bean crops.

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